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The Impact of Pruning Intensities and Non-Nutrient Ameliorants on Brazilian Spinach Growth in Floating Cultivation System

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ABSTRACT

Brazilian spinach is a highly nutritious leafy vegetable containing vitamins, minerals, and dietary fiber. This study assesses the impact of pruning intensities and non-nutrient ameliorants on Brazilian spinach growth in a floating cultivation system. The research follows a factorial randomized block design, with pruning intensity as the first factor and non-nutrient ameliorant as the second factor. Pruning intensity was categorized as light, moderate, and heavy, while the non-nutrient ameliorant included control, fine sand, rice-husk biochar, and fine sand + rice-husk biochar. The results show that moderate and heavy pruning effectively improved the response to NPK fertilization. Moderate pruning is proven to trigger the canopy area, especially starting 2 to 4 weeks after pruning. The Brazilian spinach canopy area demonstrated exponential growth and positively correlated with canopy diameter. The photosynthesis distribution in branch and shoot on moderate pruning was higher than heavy pruning, as indicated by dry weight. Moderate pruning produced a higher marketable yield than other pruning intensities. Regarding non-nutrient ameliorants, there are similarities in SPAD value, canopy area, index, dry weight, and yield. Therefore, moderate pruning is an effective practice to improve the growth and yield of Brazilian spinach, while the selected non-nutrient ameliorants have no impact.

INTRODUCTION

Brazilian spinach, scientifically known as *Alternanthera sissoo*, is a perennial tropical leafy vegetable. However, Brazilian spinach has not gained popularity in cultivation and consumption among communities, including in its habitat area. Interestingly, the edible leaf of Brazilian spinach contains beneficial dietary nutrients (Ikram et al., 2022). Therefore, Brazilian spinach has a significant chance of being the right choice to meet the daily nutritional needs of households. It is necessary to implement effective maintenance practices to ensure a year-round supply of edible leaves.

The natural process of plant aging induces a decrease in plant growth, not to mention Brazilian spinach. Consequently, there is a subsequent decline in overall growth, including the edible leaf. The plant growth underwent a deceleration in growth rate, eventually reaching a point of stagnation. Plant growth patterns tend to be similar across different plants as they age. Costa et al. (2021) reported that the plant growth pattern is described mathematically as a sigmoid curve. The sigmoid growth pattern has been confirmed in other leafy vegetables, such as cabbage (Go et al., 2022). Brazilian spinach has similar characteristics. Thus, extensive treatment is essential for this sort of plant growth phenomenon. In this context, cultivating becomes a crucial step to achieve sustainable outcomes for Brazilian spinach. This leafy vegetable, renowned for its edible leaf, relies heavily on its vegetative organs as the primary source of yield.

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Pruning and improving substrate have the potential to boost plant growth. Implementing this treatment will prevent the decrease in growth rate due to plant aging. Susanto et al. (2019) stated that vegetative and generative growth increased after the plant was pruned. The current state of the plant is a direct outcome of changes happening within its metabolism. Once pruned, plants undergo a series of metabolic alterations that heavily involve the effects of two essential hormones–indoleacetic acid and cytokinin. Xu et al. (2020) reported that pruning maintained plants' balance of indole acetic acid and cytokinin hormones. The balance of these compounds affected the growth of emerging shoots. The development of new shoots indicates the initiation of edible leaf production. This condition can improve the production period of Brazilian spinach, hence sustainable year-round commercial harvesting.

Improving the substrate with a non-nutrient ameliorant mixture plays a role in enhancing plant growth. The addition of non-nutrient ameliorants will create a suitable substrate for plant growth. Several studies have validated the efficacy of specific non-nutrient ameliorants in creating an optimal growth environment that promotes plant growth. Rice-husk biochar has been utilized as one of the substrate mixtures. This is mainly linked to the presence of water and nutrients. Japakumar et al. (2021) reported that plants with substrate mixed with rice-husk biochar demonstrated the best growth. Several leafy vegetables, including Amaranth, Corchorus, and Lettuce, have also been confirmed to increase growth when using substrate mixed with rice-husk biochar (Rodríguez-Vila et al., 2022). Substrates with sufficient water and nutrients, including those with the rice-husk biochar mixture, also have the potential to ensure the growth of Brazilian spinach.

The water requirement of mature Brazilian spinach is higher than that of younger ones. Hence, it is essential to have a cultivation system that can ensure an adequate water supply for Brazilian spinach. Floating cultivation is a cultivation system that effectively meets the water requirements of Brazilian spinach (Muda et al., 2023). Hulin & Mercury (2019) stated that capillary energy plays a role in water movement from the bottom to the substrate. This principle ensures that water is effectively supplied to the root zone (Lakitan et al., 2023).

Meanwhile, a floating cultivation system can be adopted in limited land areas while remaining economically feasible. Studies conducted by Jaya et al. (2021) have shown that implementing the floating cultivation method can enhance crop growth like celery. Adopting a floating cultivation system could be a promising solution for growing Brazilian spinach in limited land areas, especially in urban or peri-urban environments.

The implementation of floating cultivation systems for pruning and substrate enhancement has yet to become standard practice within leafy vegetable crops like Brazilian spinach. This highlights a demand for further comprehensive research exploring Brazilian spinach's growth. One potential outcome could be an increase in edible leaves produced by this crop. Understanding the specific pruning and non-nutrient ameliorant methods is crucial for optimizing Brazilian spinach's growth. The research investigates how varying pruning intensity and the application of non-nutrient ameliorant could influence Brazilian spinach growth cultivated via a floating cultivation system.

MATERIALS AND METHODS

Research Site and Agroclimatic Condition

The research was conducted at the Jakabaring outdoor facility (104°46'44''E, 3°01'35''S), Palembang, South Sumatra, Indonesia. The study was initiated on 10 July 2022 and concluded on 27 August 2022. The site belongs to the wet tropical lowland agroecosystem with an average rainfall intensity of 3.14 mm/day and air humidity fluctuating around 70% to 90%, averaging 82.96% during the research activities (Fig. 1).

Planting Resource, Treatment, and Cultivation System

The planting material used was healthy 3-month-old Brazilian spinach (*Alternanthera sissoo*) grown in pots with 27.5 cm in diameter and 27.5 cm in height. The basic substrate used as the control treatment (S0) consisted of a mixture of topsoil (75%) and chicken manure (25%) based on volume. Non-nutrient ameliorants added to the basic substrate (75%) were fine sand (25%), rice-husk biochar (25%), and a mix of fine sand + rice-husk biochar (12.5% + 12.5%), encoded as S1, S2, and S3, respectively. Pruning is carried out by cutting the lengths of the primary branches to

22.5 cm, 17.5 cm, and 12.5 cm, categorized as light (P1), moderate (P2), and heavy (P3) pruning, respectively.

The floating cultivation system used 3 rafts measuring 1 m x 2 m, which could accommodate a load of 60 kg/m^2 or 120 kg/raft. Each raft was loaded with 12 pots, arranged in 3 rows, each consisting of 4 pots. Each pot was positioned at an equal distance to maintain the stability of the raft and ensured that the bottom of the pot was in direct contact with the water surface, i.e., the upper surface of the raft was submerged in water 1-2 cm deep. Direct contact between the substrate and the water surface allows the water to continuously move up to keep the substrate wet due to the capillarity force.

Non-nutrient ameliorants such as sand and biochar improved the quality of substrate physical properties but did not significantly increase the availability of macronutrients needed by plants. To overcome this, it was necessary to apply NPK fertilizer at a dose of 3 g/pot 10 days after pruning. The response of Brazilian spinach to NPK fertilizer application was monitored every 2 days, starting after fertilization and continuing until 12 days after.

Data Collection

The data carried out included morphological characteristics of the plant and the condition of the substrate during the study. Nondestructive data collection on plants was carried out for SPAD values, canopy area (CA), canopy index (CI), canopy diameter (CD), and canopy temperature (CT). In contrast, soil temperature and moisture measurements are implemented for the substrate. The canopy area was measured using an Android digital image scanner (Easy Leaf Area, developed by Easlon & Bloom, 2014). The canopy diameter was measured using a measuring tape on the widest side of the canopy.

In the meantime, the canopy index was expressed as the ratio of the canopy area measured using a digital image scanner to the value calculated by the widest diameter. SPAD value was measured using the chlorophyll meter (SPAD-502 Plus, Konica Minolta Optics, Osaka, Japan), canopy temperature using a thermal camera (Teledyne FLIR C3-X Compact Thermal Camera, Mouser Electronics, Inc., Mansfield, Texas USA). In contrast, the soil moisture and temperature were monitored using a Zentra ZL6 data logger (Labcell Ltd, Mansfield Park, Hants, UK).

Meanwhile, the destructive data collection was fresh weight of marketable leaf (FWM), dry weight of leaf (DWL), dry weight of branch (DWB), and dry weight of stem (DWS). Harvesting was done simultaneously with destructive data collection, carried out per replication every week starting from 5 to 7 weeks after planting (WAP).

The dry weight of plant components was collected after being heated in the oven at a temperature of 100^{o}C for 24 hours or more until a constant weight was reached.

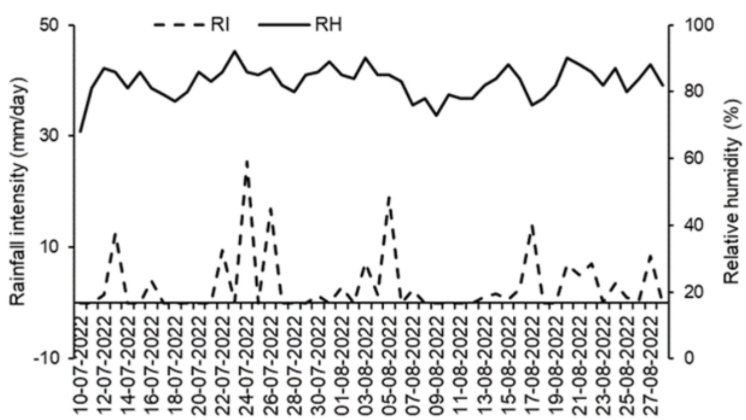


Fig. 1. Average rainfall intensity (RI) and relative humidity (RH) in the research location (Source: Indonesian Agency for Meteorological, Climatological and Geophysics)

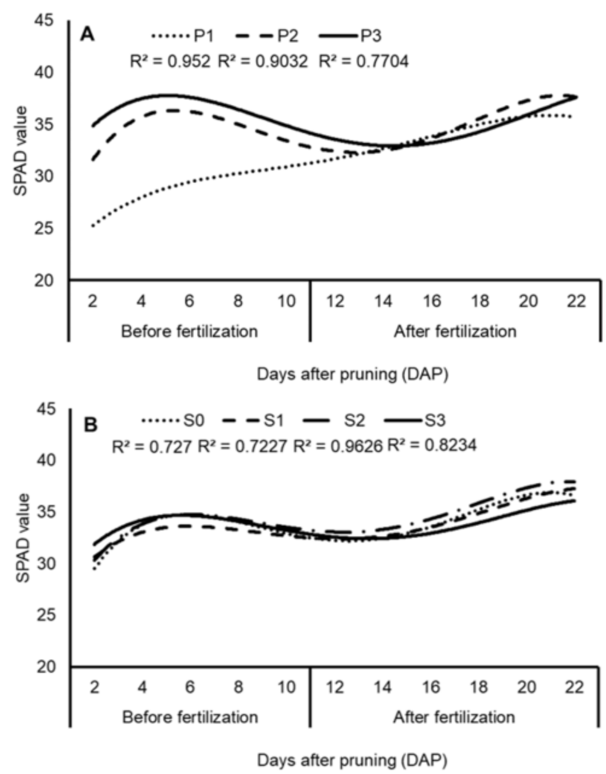
Data Analysis

The effect of pruning intensity on the primary branches of Brazilian spinach and the application of non-nutrient ameliorants, namely fine sand and/or rice-husk biochar, were revealed by analysis of variance (ANOVA). Significant differences among treatments were tested using Tukey's honestly significant difference (HSD) procedure at $P<0.05$. Regression analysis was done to determine the relationship between related variables, and the coefficient of determination (R^2) was used to indicate the strength of the relationship. The analysis was performed using RStudio software version 2023.06.0+421 for Windows (developed by the RStudio team, PBC, Boston, MA).

RESULTS AND DISCUSSION

Monitoring the Response of Each Treatment to NPK Fertilization

The leaf SPAD value tended to increase as soon as the pruning was carried out, except for lightly pruned plants. This phenomenon indicated that the improved value of SPAD contributed to enlarging young leaves due to pruning treatment; however, this increase lasted only a short time for about 4 days. Brazilian spinach has also shown positive results from NPK fertilization at a dose of 3 g/plant, as proven by increased leaf SPAD value. This positive response was observed in all ameliorant applications and pruning intensities. The positive response to fertilizer application extended longer, about 10 days before the SPAD value declined (Fig. 2).



Remarks: P1: light pruning; P2: moderate pruning; P3: heavy pruning; S0: control; S1: fine sand (25% v/v); S2: rice-husk biochar (25% v/v); S3: fine sand + rice-husk biochar (12.5% + 12.5% v/v)

Fig. 2. The response of Brazilian spinach to NPK fertilization in plants treated with pruning and non-nutrient ameliorants as indicated by the SPAD value

The SPAD value has been widely used as a nondestructive indicator of leaf nitrogen and chlorophyll content and has been tested in various cases. The SPAD value can accurately reflect leaf nitrogen and chlorophyll content with a high level of reliability. The SPAD value as an indicator of nitrogen and chlorophyll content has also been observed in other leafy vegetables such as romaine lettuce (Mendoza-Tafolla et al., 2019), bok choy (Ji et al., 2020) and *Cnidoscolus aconitifolius* (Gustiar et al., 2023).

Based on the observations, pruning has been proven to improve the SPAD value of Brazilian spinach leaves. However, there may be a subsequent decrease in a short period. As a leafy herbaceous vegetable, pruning is necessary for Brazilian spinach to enhance the SPAD value of its leaf. The impact of pruning on increasing the SPAD value has been observed in other herbaceous plants, such as cherry tomatoes (Ahmad et al., 2017). Pruning induces the growth of young leaves, which subsequently leads to an elevation in the nitrogen and chlorophyll of the leaves. The SPAD value increases as the leaf expands and decreases as it ages. A similar phenomenon has been observed in other leafy vegetables, such as water spinach, red amaranth, and green amaranth (Alam et al., 2022).

In addition to pruning, fertilization is another treatment that plays a role in increasing the SPAD value. Brazilian spinach exhibits increased SPAD value as a response to fertilization (Fig. 2). Fertilization had been determined to enhance the accumulation of nutrients and chlorophyll in the leaf, resulting in an increased SPAD value after fertilization application. Increased SPAD value after fertilization has also been observed in other leafy vegetables, such as kale and Swiss chard (Abiya et al., 2022). Furthermore, Lakitan et al. (2021) emphasized that fertilization had gradually increased the SPAD value, which will decrease again when the available nutrients from the applied fertilizer diminish. Hence, the SPAD value can also be used as an indicator for determining the appropriate timing of plant fertilization.

Brazilian Spinach Growth on Pruning Intensities and Non-Nutrient Ameliorants

Heavy pruning still cannot match the canopy area of moderate and light-pruned plants even after 4 weeks. Meanwhile, moderately pruned plants are comparable to lightly pruned ones in just 2 weeks. The moderate pruned plant performed better in Brazilian spinach based on the recovery speed. Meanwhile, the application of non-nutrient ameliorants did not affect the canopy area (Fig. 3).

Moderate pruning has been confirmed to enhance canopy growth, as indicated by an increase in canopy area. This pruning stimulates branch elongation and the development of wider young leaves. Pruning promotes the elongation of internodes in the branches. Meanwhile, simultaneous initiation of young leaves occurs as indicated by an expansion in the leaf area (du Toit et al., 2020). The contribution of increased growth in canopy organs such as branches and leaves will stimulate plant growth with a broader new canopy (Thakur et al., 2018). This phenomenon was observed during moderate pruning, where new branches and leaves grew, leading to a wider canopy of Brazilian spinach than other pruning intensities.

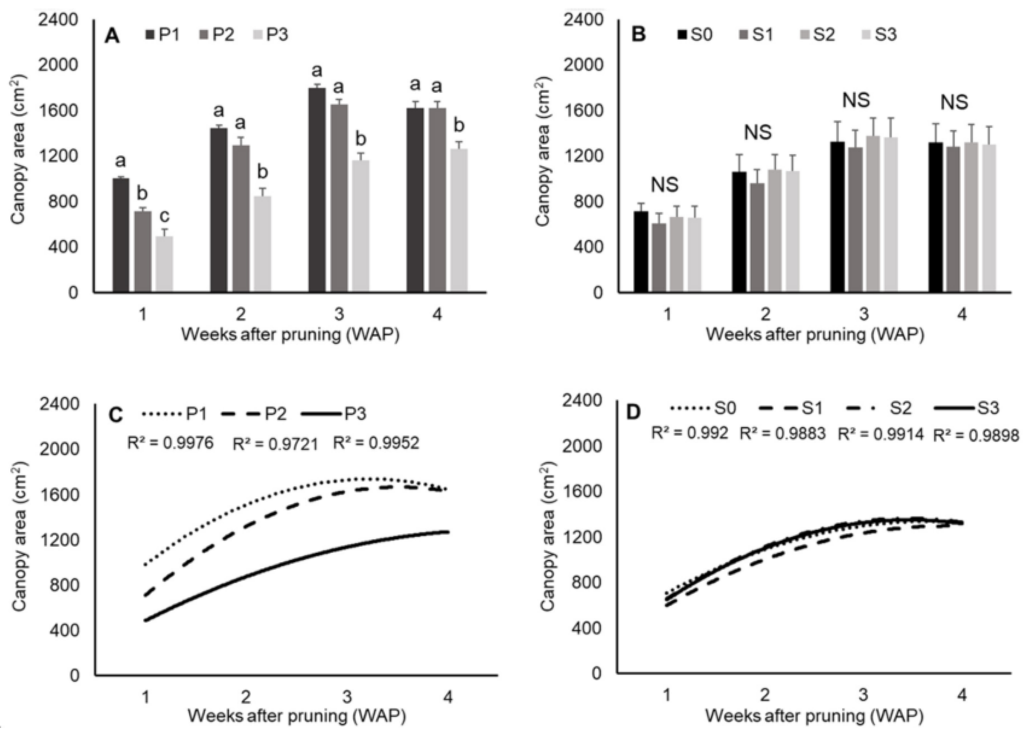
The application of non-nutrient ameliorants, including fine sand, rice-husk biochar, and their combination of two, did not demonstrate any significant differences. No notable effects on plant growth were observed from these treatments. The addition of fine sand and rice-husk biochar into the substrate did not yield statistically significant differences, specifically concerning the growth of the plant being examined. Similarly, the use of non-nutrient ameliorants has been observed to have no significant effect on the growth of several tested plants, such as lettuce and cabbage (Carter et al., 2013). The application of non-nutrient ameliorants did not directly affect plant growth. Instead, the impact of non-nutrient ameliorant application was more dominant in improving substrate conditions.

The canopy index was unaffected by the pruning intensity, and the application of non-nutrient ameliorants was observed 3 and 4 weeks after pruning in Brazilian spinach. However, the difference in the canopy index was seen in weeks 1 and 2. This symptom occurred due to the re-development of new branches and leaves after pruning. In addition, the canopy index was lower in plants where the basic substrate was mixed with non-nutrient ameliorants of fine sand (Fig. 4). The canopy index is directly proportional to the leaf density of the canopy in question.

The canopy index reflects the leaf density that constitutes the canopy. Dense foliage contributes to an increased canopy index, and pruning plays a role in encouraging the growth of new leaves. The pruned plants showed a higher leaf count than the non-pruned ones (Kumar et al., 2018). Pruning facilitated the development of new foliage, leading to a distinctive canopy configuration. The vigorous growth of these young leaves contributes to forming a denser and more compact canopy.

The canopy index of the fine sand substrate mixture showed a lower value compared to other treatments with non-nutrient ameliorants. This was particularly evident at 2 weeks after pruning (WAP). The observed phenomenon was attributed to the limited water availability for the recovery of Brazilian spinach growth, including its leaves, following the pruning activity. According to Alghamdi et al. (2022), sandy substrates' water-holding capacity was lower than rice-husk biochar. The limited water in the fine sand substrate mixture noticed the decrease in leaf growth. Insufficient water supply inhibits leaf growth, which is also observed in the treated Brazilian spinach, resulting in a lower canopy index.

There is a linear relationship between the canopy diameter and the canopy area, suggesting that the leaf density in the canopy did not depend on the size of the canopy of the Brazilian spinach (Fig. 5). Several methods have been used to measure canopy density (Fasil et al., 2022). Nevertheless, canopy diameter can be used to estimate the canopy area for Brazilian spinach. Plants with wide canopy diameters and evenly distributed leaves will increase the canopy area. Conversely, canopies with stacked leaves and narrow diameters will result in a smaller canopy area. Therefore, the canopy area is not solely dependent on leaf density.



Remarks: P1: light pruning; P2: moderate pruning; P3: heavy pruning; S0: control; S1: fine sand (25% v/v); S2: rice-husk biochar (25% v/v); S3: fine sand + rice-husk biochar (12.5% + 12.5% v/v). Different letters above the standard error bars indicate significant differences based on Tukey's HSD at $P<0.05$. Meanwhile, the NS indicates non-significant differences based on Tukey's HSD at $P<0.05$

Fig. 3. Effect of pruning intensity (A) and non-nutrient ameliorant application (B) on canopy area in Brazilian spinach and their enlarging trends for the first four weeks (C and D)

An increase in the canopy temperature can indicate a decrease in leaf water content and soil moisture or a reduction in the ability of roots to absorb and transport water to the above-ground organs. Based on the image captured by a thermal camera, the high temperature (red color) was predominant in Brazilian spinach plants whose base substrate was added with fine sand as the selected non-nutrient ameliorant and light as well as moderate-pruned plants of control plants (P1 and P2) (Fig. 6).

Higher canopy temperature in the plants grown on sand-added substrate was probably due to lower substrate moisture content. Sand has been recognized as having a low water-holding capacity. Meanwhile, higher canopy temperatures in the lightly and moderately pruned plants were due to the higher water loss through transpiration. The broader the leaf surface directly exposed to sunlight, the greater the light energy absorbed to increase the temperature of the canopy.

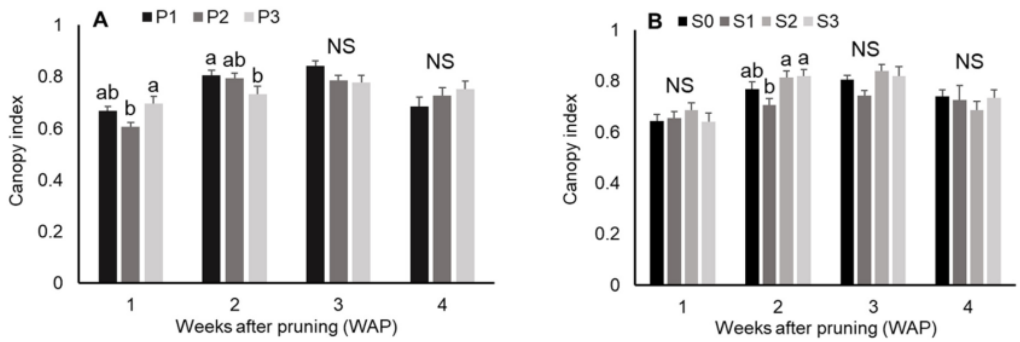


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Fig. 4. Effects of pruning intensity (A) and non-nutrient ameliorant application (B) on canopy index in Brazilian spinach (C and D)

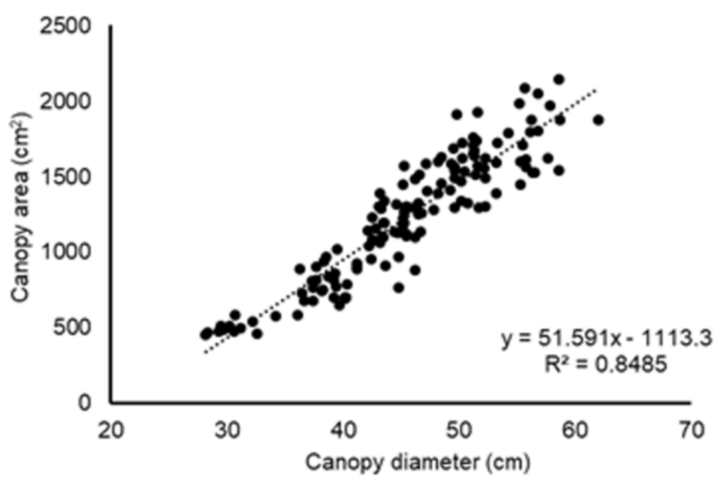
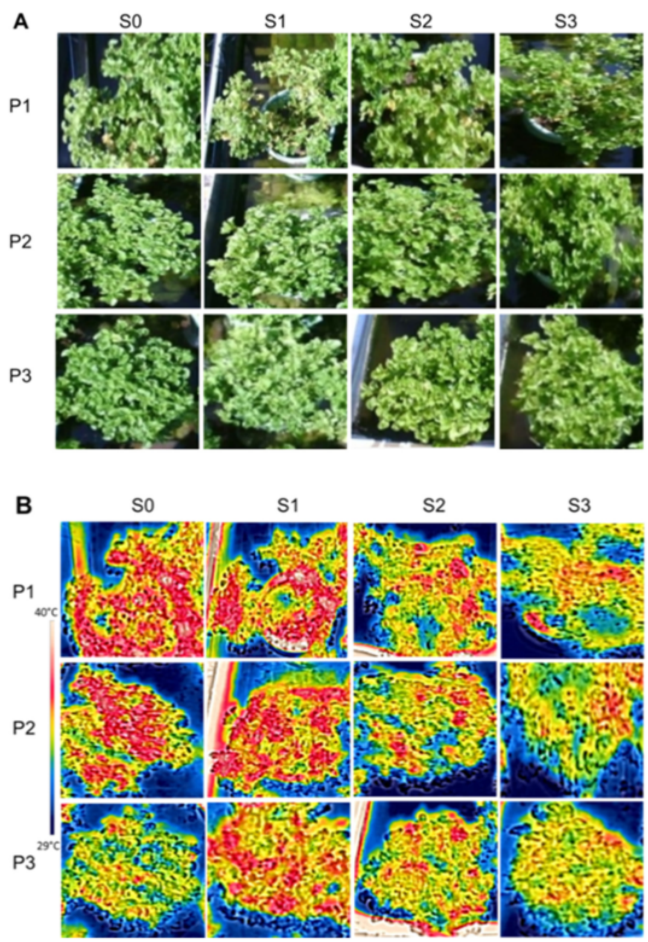


Fig. 5. Linear relationship between canopy diameter and canopy area in Brazilian spinach

Each non-nutrient ameliorant has a different capacity to fulfill the plant's growth requirements. The substrate mixed with fine sand had a lower water retention capacity than other substrate mixtures. According to Shomana et al. (2020), adding sand to the substrate accelerates water loss, as seen by the substrate moisture level. This phenomenon is attributed to the substrate's increased presence of macro pores. The existence of macro pores in the substrate limits water retention, reducing moisture levels within the substrate. As the canopy temperature indicates, this insufficient water supply negatively impacts the plants' metabolic functions. Hou et al. (2019) further elucidated that an increase in canopy temperature can indicate a water-deficient plant.

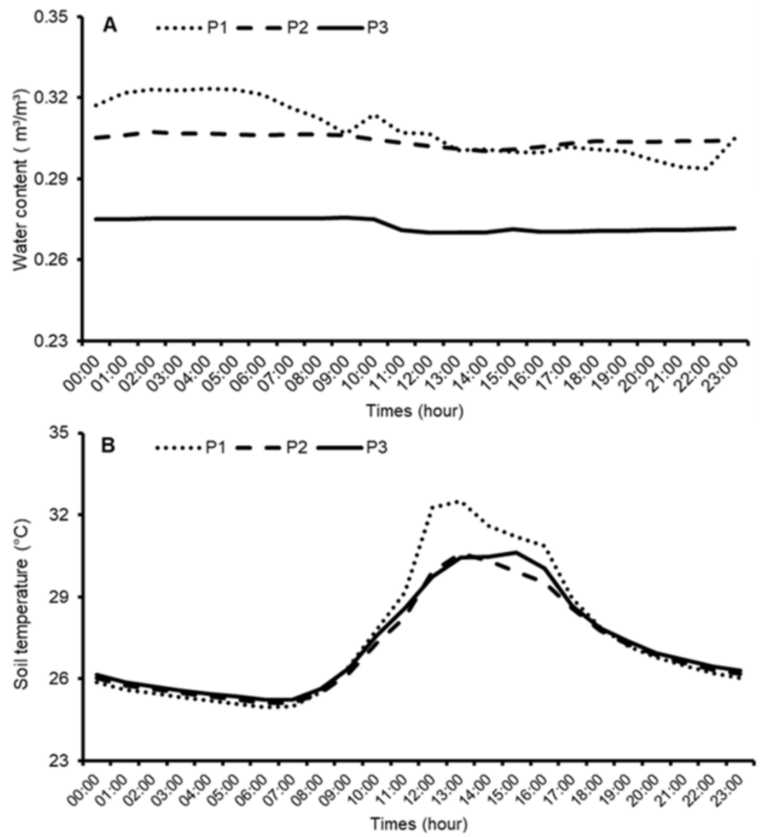


Remarks: Rows for pruning intensities (P1: light pruning; P2: moderate pruning; P3: heavy pruning) and columns for non-nutrient ameliorant applications (S0: control; S1: fine sand (25% v/v); S2: rice-husk biochar (25% v/v); S3: fine sand + rice-husk biochar (12.5% + 12.5% v/v). Red color represents higher and blue color represents lower canopy temperature

Fig. 6. The canopy of Brazilian spinach captured at around midday using regular (A) and thermal camera (B) at 4 weeks after pruning

Plants with a broader canopy exhibit higher transpiration rates. Light and moderate pruning in plants results in a canopy that tends to be wider than heavy pruning, leading to increased transpiration in these plants. Transpiration leads to water loss in plants. Higher transpiration rates indicate an increased water requirement, and inadequate water supply can lead to elevated canopy temperature. Gonzalez-Dugo et al. (2020) suggested a correlation between canopy temperature and plant transpiration. This implies that a higher canopy density increases transpiration and canopy temperatures. This was due to the role of water in absorbing and regulating heat energy. Therefore, pruning is a recommended technique for enhancing water efficiency in cultivation.

The small size of the canopy during heavy pruning causes increased evaporation. This phenomenon decreases water compared to light and moderate pruning. On the other hand, light pruning triggers higher transpiration. The higher substrate temperature peaks on light pruning illustrate the higher transpiration. The substrate's water and temperature amounts changed as they reached 10:00 AM. The moisture of the substrate gradually decreased while the substrate temperature increased. The substrate temperature continued rising until it peaked at 13:00 PM. During that time, evaporation and transpiration were predicted to occur at their maximum level (Fig. 7).



Remarks: P1: light pruning; P2: moderate pruning; P3: heavy pruning

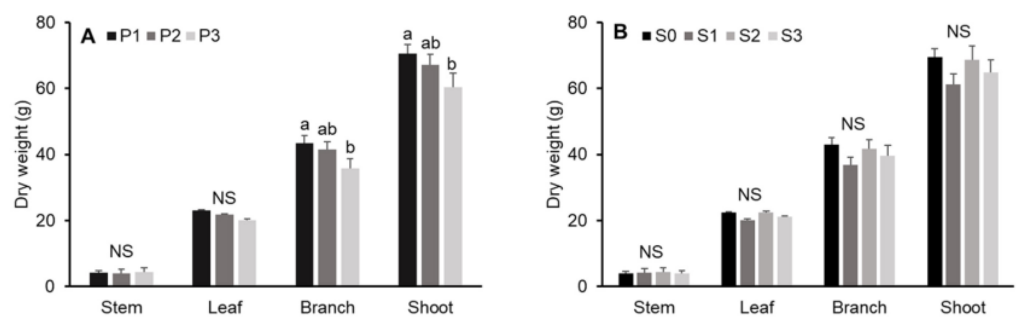
Fig. 7. Effects of pruning intensity on substrate water content (A) and temperature (B)

Evaporation and transpiration impact the substrate conditions, including the water amount and substrate temperature. Evaporation leads to water loss from the growing media. Water loss from the growing media due to evaporation primarily occurs in plants with smaller canopy sizes because the canopy cannot cover the entire surface of the substrate. On the other hand, substrate conditions are also influenced by plant transpiration. Transpiration releases water from plant tissues sourced from the water content in the substrate. That will contribute to a rise in substrate temperature due to a decrease in water, which plays a role in temperature regulation. According to Chen et al. (2019), transpiration from a larger canopy significantly contributes to water loss in the substrate. This water loss was reflected in an increase in substrate temperature.

Solar radiation is one of the factors that determines the evapotranspiration rate. Based on observations, it was known that evaporation and transpiration start to occur significantly around 13:00, as indicated by the decreased substrate water and temperature. During that period, solar radiation is predicted to reach its maximum point, reaching the surface of the substrate and plants triggering maximum evapotranspiration. This is consistent with Adnan et al. (2020)'s findings, which emphasized that solar radiation was the most sensitive factor in evapotranspiration.

The ability of Brazilian spinach to recover from pruning was excellent. This was shown by organ growth, especially in branches and shoots during moderate pruning. However, heavy pruning had a lower growth tendency. This phenomenon also occurs in the substrate of sand, which has a more inferior growth tendency (Fig. 8).

Pruning was indicated to promote the growth of Brazilian spinach. This is associated with enhanced photosynthesis and specific stimulation. Pruning improves photosynthetic efficiency, as demonstrated by better vegetative growth in pruned plants. Mota et al. (2020) added that pruning triggered the vegetative cycle and nutrient flow. Optimal nutrient flow enhances the rate of photosynthesis, which in turn leads to improved plant growth through increased photosynthetic metabolism. In addition to its association with photosynthesis, pruning stimulates the production of hormones that promote plant growth. Atmaca & Ulger (2021) reported that pruned plants exhibit higher levels of the hormone indole acetic acid (IAA). The plant containing the hormone IAA has the potential to stimulate plant growth. This regulation allows pruned Brazilian spinach to recover its vegetative organs quickly.



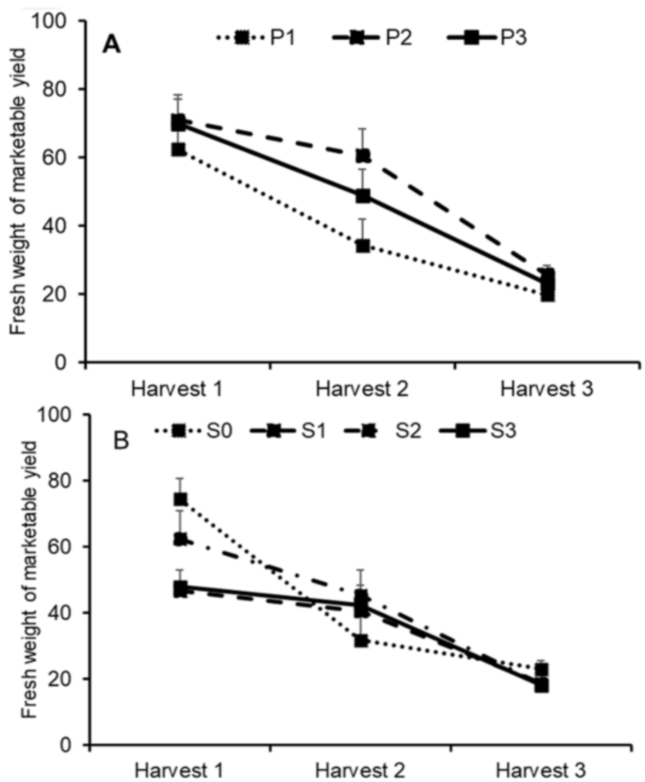
Remarks: P1: light pruning; P2: moderate pruning; P3: heavy pruning; S0: control; S1: fine sand (25% v/v); S2: rice-husk biochar (25% v/v); S3: fine sand + rice-husk biochar (12.5% + 12.5% v/v). Different letters above the standard error bars indicate significant differences based on Tukey's HSD at $P<0.05$. Meanwhile, the NS indicates non-significant differences based on Tukey's HSD at $P<0.05$

Fig. 8. Photosynthesis distribution on different pruning intensities (A) and non-nutrient ameliorants application (B)

Regarding the treated substrates, there was no significant difference in the growth of Brazilian spinach among the different non-nutrient mixtures. However, the substrate mixture with fine sand showed a tendency for the lowest accumulation of photosynthetic yield in each vegetative organ. Including sand in the substrate mixture creates adverse conditions for plant growth. Flores-Ramírez et al. (2018) state that sandy substrates have low water content and pH, hindering nutrient solubility and plant availability. The presence of sand in the substrate mixture is suspected to be why Brazilian spinach shows a lower growth tendency than other non-nutrient ameliorant treatments.

The marketable yield that edible leaves of Brazilian spinach experience declines as the plant ages. Moderate to heavy pruning maintained a lower marketable yield decline than light pruning. Meanwhile, the substrate from rice-husk biochar was also able to preserve the decrease in the marketable yield of Brazilian spinach compared to other substrate mixtures (Fig. 9).

Pruning promotes the growth of plant canopy components, including its leaf. Pruned plants exhibit the development of new canopy characteristics. The pruned plants initiate the growth of broader leaves. Meanwhile, pruning also stimulates faster leaf expansion (Kathiresan et al., 2019). This phenomenon will result in modifying the canopy characteristics, ultimately leading to a greater availability of commercial leaves.



Remarks: P1: light pruning; P2: moderate pruning; P3: heavy pruning; S0: control; S1: fine sand (25% v/v); S2: rice-husk biochar (25% v/v); S3: fine sand + rice-husk biochar (12.5% + 12.5% v/v)

Fig. 9. Marketable yield of Brazilian spinach on different pruning intensities (A) and non-nutrient substrate mixtures (B). Each harvest was carried out at different times, namely: Harvest 1 at 5 WAP, Harvest 2 at 6 WAP, and Harvest 3 at 7 WAP

In addition to yielding higher-quality commercial young leaves, pruning also helps prevent damage to commercial leaves caused by pests and diseases. Sharma & Singh (2018) reported that pruning has been proven to reduce plant damage caused by pests. Pruning is beneficial in mitigating yield losses caused by pests and diseases in various herbaceous plants, including chili peppers (Setiawati et al., 2022). Regarding this matter, moderate and heavy pruning has resulted in higher preservation of commercial leaves compared to unpruned plants.

Based on the observation, the substrate mixture from rice-husk biochar had shown the ability to sustain harvest yields up to harvest 2 (6 WAP). Li et al. (2020) reported that adding rice-husk biochar to the substrate increases nitrogen utilization efficiency. Furthermore, rice-husk biochar enhances the plant's nutrient absorption capacity as a substrate amendment. Meanwhile, rice-husk biochar is a substrate mixture that can improve the substrate's ability to retain water, making it available for plants. This condition contributes to Brazilian spinach's growth, including preserving its commercial leaves.

CONCLUSION

Moderate pruning is a practice that stimulates Brazilian spinach's growth more effectively than other pruning intensities. Meanwhile, the application of non-nutrient ameliorants did not enhance the growth of Brazilian spinach. Therefore, moderate pruning should be practiced to improve Brazilian spinach's growth and yield.

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